TITLE: Properties of Wide Mesastripe InGaAsP Heterolasers

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Properties of wide mesastripe InGaAsP heterolasers

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Abstract. InGaAsP/InP wide mesastripe laser diodes ($\lambda = 1.3-1.55$ μm) grown by metal-organic chemical vapour deposition (MOCVD) method have been fabricated. Light-current characteristics and emitting spectra under pulse and continuous-wave (CW) operation have been investigated in $10-60$°C temperature range. Laser diode active region overheating of 30–60 K in respect to the copper heatsink at maximum CW drive currents has been determined. Strong influence of the external differential quantum efficiency temperature dependence on CW maximum output power has been established. Optical output powers of 3 W and 2.6 W under CW operation, 9 W and 6.5 W under pulse operation have been reached for a single 100 μm-wide aperture mesastripe InGaAsP/InP laser diodes emitting at 1.3 μm and 1.55 μm wavelength, respectively.

Introduction

At present time there is a great interest in laser radiation with high output power. Record-high CW optical output power of 11 W has been reached for 0.98 μm laser diodes (LDs) [3–5]. 5 W CW output power in InGaAsP/InP 1.48 μm diode lasers with 200 μm mesastripe width has been achieved [11]. Such discrepancy in the record values of output power is mainly explained by the difference in the energy band structure of AlGaAs/GaAs and InGaAsP/InP solid solutions [8].

In this paper we investigate the properties of MOCVD-grown InGaAsP/InP separate confinement LDs [9] with the aim to determine the primary factors limiting maximum optical output power.

1. Experimental samples

Separate confinement heterostructure with two strained quantum well active layers was the basic structure for LD fabrication [3–5, 9]. The waveguide thickness of 0.9 μm was chosen. Further increase of the waveguide thickness is not reasonable due to high-order optical modes lasing [5]. The waveguide doping level and free carrier concentration in p-type and n-type cladding layers were 10^{16} cm^{-3} and 10^{17} cm^{-3} respectivly, as it further reduction would lead to the increase of structure series resistance. Solid solution composition of the waveguide layer was chosen to provide $4kT$ quantum well depth for electrons. The waveguide bandgaps were defined as 1.25 eV and 1.1 eV for laser heterostructures emitting at 1.3 μm and 1.55 μm wavelength, respectively.

2. Experimental results and discussion

Light-current characteristics in pulse regime were investigated at 2 μs pulse duration. In this case a slight active region overheating is observed only at pump currents higher than 10 A in LDs with 1.5–2 mm cavity length (Fig. 1(a)). However, pulsed optical output power

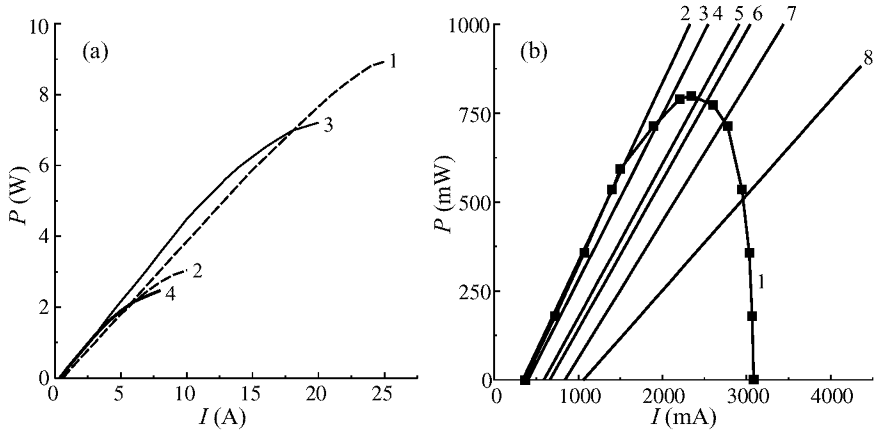

Fig. 1. (a) CW (curves 1, 3) and pulse (curves 2, 4) output power versus current at 10°C heatsink temperature for LDs emitting at 1.3 μm wavelength ($L = 2$ mm; curves 1, 2) and 1.55 μm wavelength ($L = 1.2$ mm; curves 3, 4). (b) CW (curve 1) and pulse (curves 2–8) light-current characteristics for 1.55 μm LD with 500 μm cavity length. Heatsink temperature: 1, 2—11°C, 3—14°C, 4—20°C, 5—34°C, 6—41°C, 7—50°C, 8—56°C.

of 9 W and 6.5 W were reached in laser diodes emitting at 1.3 μm and 1.55 μm wavelength, respectively.

Strong active region overheating resulting in the saturation of light-current characteristics was observed for LDs operating in CW regime (Fig. 1(b)). Nevertheless CW optical output power of 3 W and 2.5 W were obtained in long cavity ($L = 1.5-2$ mm) 100 μm-wide mesastripe LDs emitting at 1.3 μm and 1.55 μm wavelength, respectively (Fig. 1(a)). The obtained results are comparable with record output power values of this wavelength range [11].

The temperature of LDs active region was determined in two different ways. The comparison of light-current characteristics of laser diode measured under CW operation at 10°C heatsink temperature and under pulse operation at different temperatures higher than 10°C was carried out (Fig. 1(b)). In the point of intersection of light-current curves the active region overheating was determined as the difference between temperature values of the heatsink. In the second method the active region overheating was calculated from the difference of emitting spectra peak positions under pulse and CW operation.

The value of active region overheating determinated by both methods coincided with ±2 K accuracy and was 30–60 K at maximum CW drive currents depending on LD cavity length.

It is necessary to point out, that in the investigated samples we succeeded to reduce the reciprocal series resistance of laser heterostructure down to 10^{-4} Ω/cm^2.

The dependence of characteristic temperature T_0 on LD cavity length is shown in Fig. 2. This dependence is typical for LDs based on conventional separate confinement heterostructures with thin active region [11]. Even in short cavity LDs in the 30–40 K temperature range the influence of threshold current increase on maximum output optical power is not essential in comparison with the external differential quantum efficiency (η_d) temperature dependence (Fig. 1(b)), that coinsides with [6].

The dependence of characteristic temperature T_1 on LD cavity length (Fig. 2) has an opposite behaviour compared to the T_0 dependence. T_1 parameter characterizes the tem-

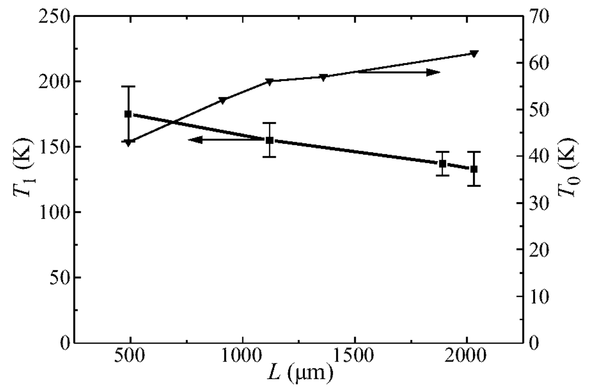

Fig. 2. Characteristic parameters T_0 and T_1 dependencies versus LDs cavity length.

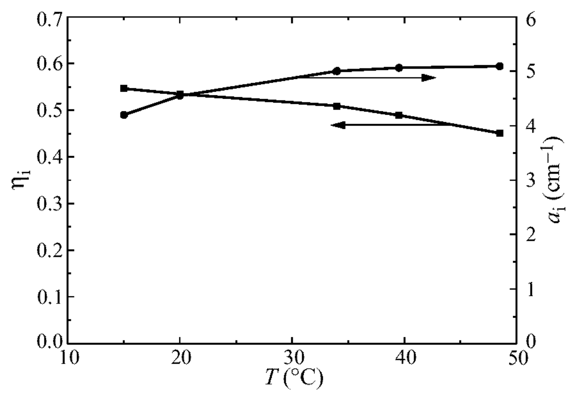

Fig. 3. Temperature dependencies of internal optical losses α_i and internal quantum efficiency η_i.

perature dependence of η_d [7]. Low value of T_1 parameter 140–180 K in LDs on the base of InGaAsP/InP solid solutions is an essential point. The result is drastic decrease of η_d with active region overheating observed for both short cavity (Fig. 1(b)) and long cavity (Fig. 1(a)) InGaAsP/InP LDs, substantially limiting maximum output power. In GaAs-based LDs T_1 parameter reaches 300–1600 K values [7].

The $1/\eta_d(L)$ dependencies plotted in the $10-50$°C temperature range allowed to determine temperature dependencies of internal optical losses (α_i) and internal quantum efficiency (η_i) (Fig. 3). To reduce the influence of α_i temperature dependence on η_d is possible only by decreasing the α_i value. η_i value quantitatively characterizes the presence of carrier leakage and nonradiative recombination channels in heterostructure above threshold. To reduce the influence of η_i temperature dependence on η_d is possible by decreasing the carrier leakage and nonradiative recombination channels.

Conclusion

InGaAsP/InP wide mesastripe lasers have been fabricated and studied. Optical output powers of 3 W and 2.6 W under CW operation, 9 W and 6.5 W under pulse operation have been obtained for 1.3 μm and 1.55 μm wavelength,respectively. Under CW operation LD active region overheating of 30–60 K in respect to the copper heatsink has been determined. It has been established, that along with internal optical losses and series resistance the temperature dependence of the external differential quantum efficiency strongly affects CW maximum output power. Due to low values of T_1 parameter this influence is more dramatic for InGaAsP/InP laser diodes. To limit the negative influence of T_1 is possible only by reducing the internal optical losses and carrier leakage in laser heterostructure.

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